Design and Development of a Blind Person Assistant

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Motivation

Visually impaired students on campus expressed the need for an indoor navigation solution beyond traditional options like mobile applications, GPS systems, or guide dogs that came with their own disadvantages. Our team was motivated to design and develop an IoT real-time blind person assistant device powered by AI that integrated with a white cane; a tool that most visually impaired individuals are already familiar with. The device aims to help with the nuances of indoor navigation, such as obstacle detection and avoidance, obstacle notification, and guidance to destinations.

Project Objectives

Core objectives of this project include:

- Assisting with indoor navigation in real-time
- Integration with a pre-existing white cane
- No reliance on GPS for indoor navigation
- Offering an ergonomic and near hands-free experience
- Notifying the user through haptic feedback and text-to-speech audio
- Detecting and classifying objects using machine learning in real-time
- Tracking and avoiding objects through computer vision and guidance through gyro sensors, haptic feedback, and text-to-speech audio output
- Ability to scan signs through image-to-text scanning tools in the cloud

Technologies Used

PyTorch, Luxonis, NoPorts by Atsign, aws, Flask, 360

Overall System Architecture

Design & Implementation

Our IoT-based indoor navigation blind person assistant contains three main components: the Headset, the System Gateway, and the Smart Cane.

The **Headset** is composed of a camera, speaker, and a gyro sensor, acting as the visual guide. We trained our own machine learning model using YoloV8 Nano as a base model; a great choice for real-time embedded systems. Our model is trained on over 300+ images on campus that we captured and manually labeled with bounding boxes ourselves. The model can detect several objects including garbage cans, wet floor signs, doors, and exit signs. The Luxonis Oak-D Lite camera provides a 4K RGB center camera for object detection plus two stereo cameras for depth perception, with an onboard VPU for efficient edge inference.

The **System Gateway** functions as the command center, housing a Raspberry Pi, router, and power bank that manages all networking and core logic. It connects to the Headset via USB/wires and to the Smart Cane wirelessly. The system architecture includes specialized modules for computer vision, gyroscopic data processing, camera control, vibration feedback, and system integration, all organized across 5 MQTT topics, 8 SystemD services, and 10 API endpoints.

The **Smart Cane** enhances navigation through dual push buttons for user input and vibration motors for directional haptic feedback. It incorporates relay modules, a gyro sensor, WAGO connectors, and a power bank with its own Raspberry Pi. This component operates semi-statelessly, transferring sensor data via MQTT while receiving real-time guidance based on the angular relationship between headset and cane orientation. Pitch, Yaw, and Roll values are computed onboard and are also outputted on its own MQTT topic.

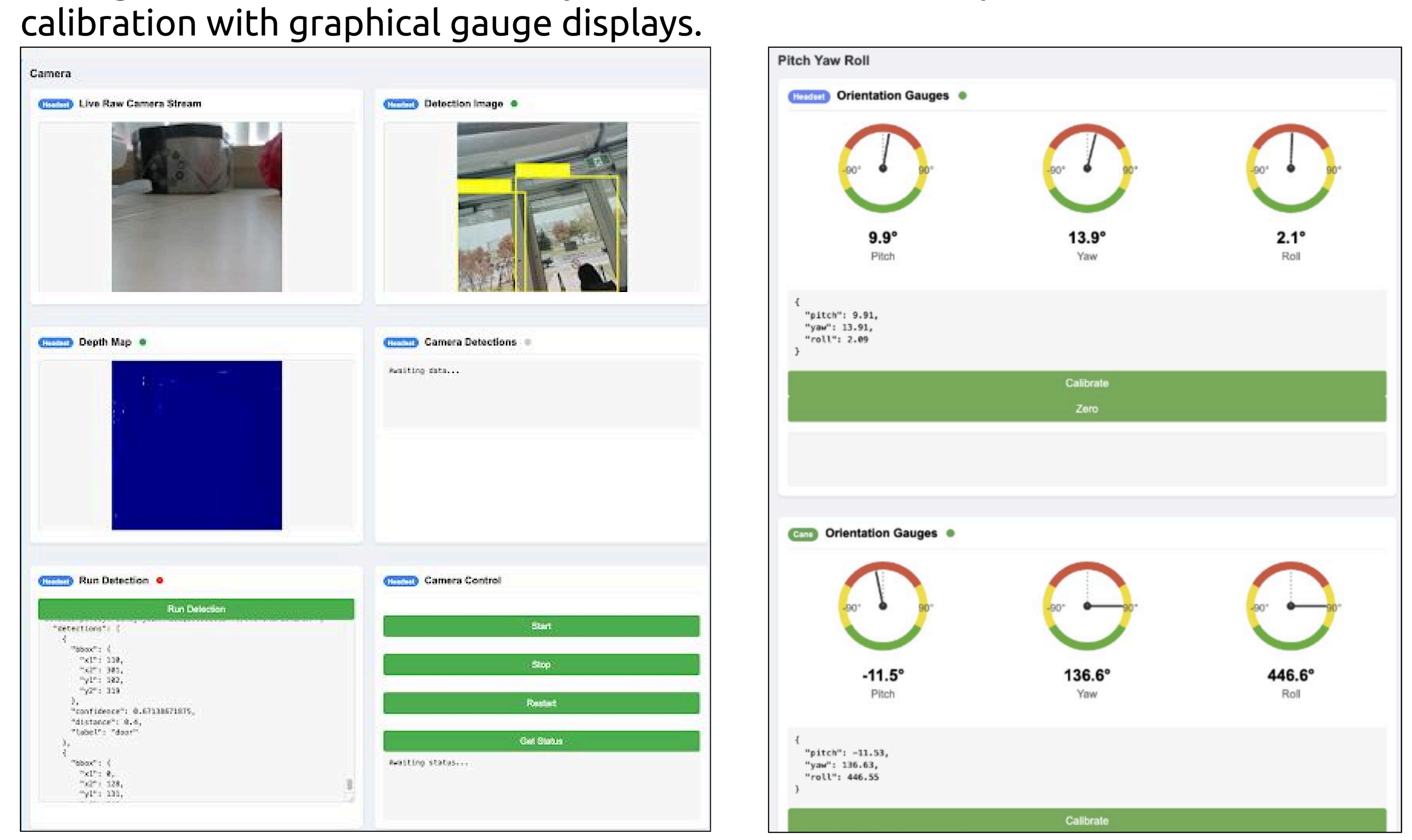
With these three components working in unison, our system delivers four powerful navigation features:

1. Detection Narration → verbally announces objects detected by the camera
2. Obstacle Avoidance → real-time guidance to help users avoid obstacles
3. Object Tracking → real-time guidance to help users locate specific objects
4. Sign Scanning → converts text on signs into audio output

The dashboard's features are accessible through an audible menu, which also includes personalization options such as adjustable volume, text-to-speech speed, and language preferences in either English or French.

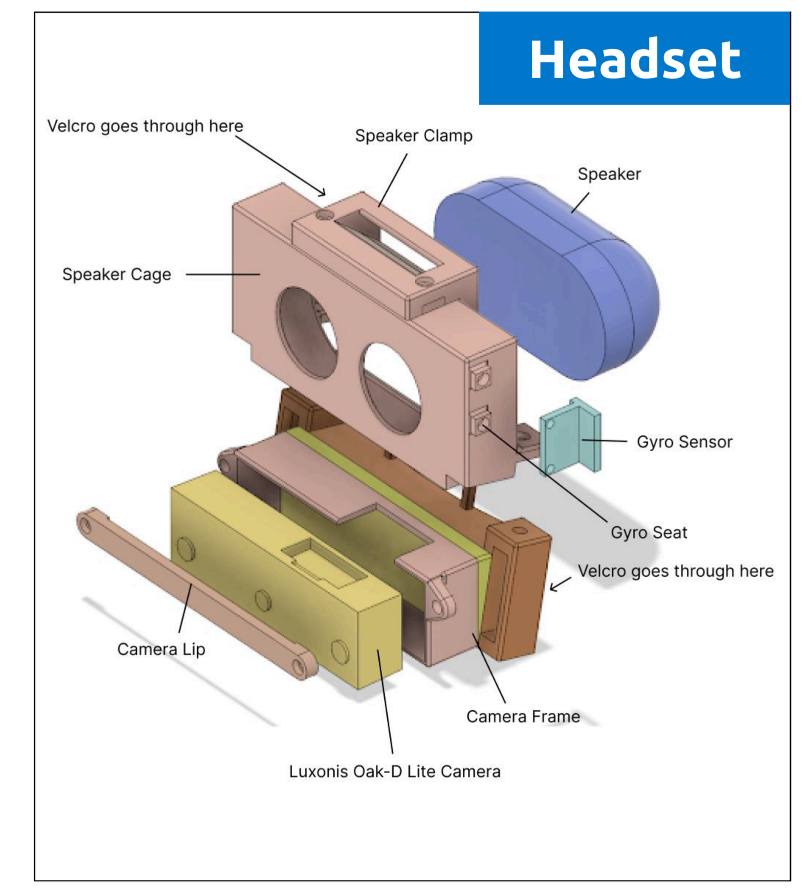
Debug Dashboard

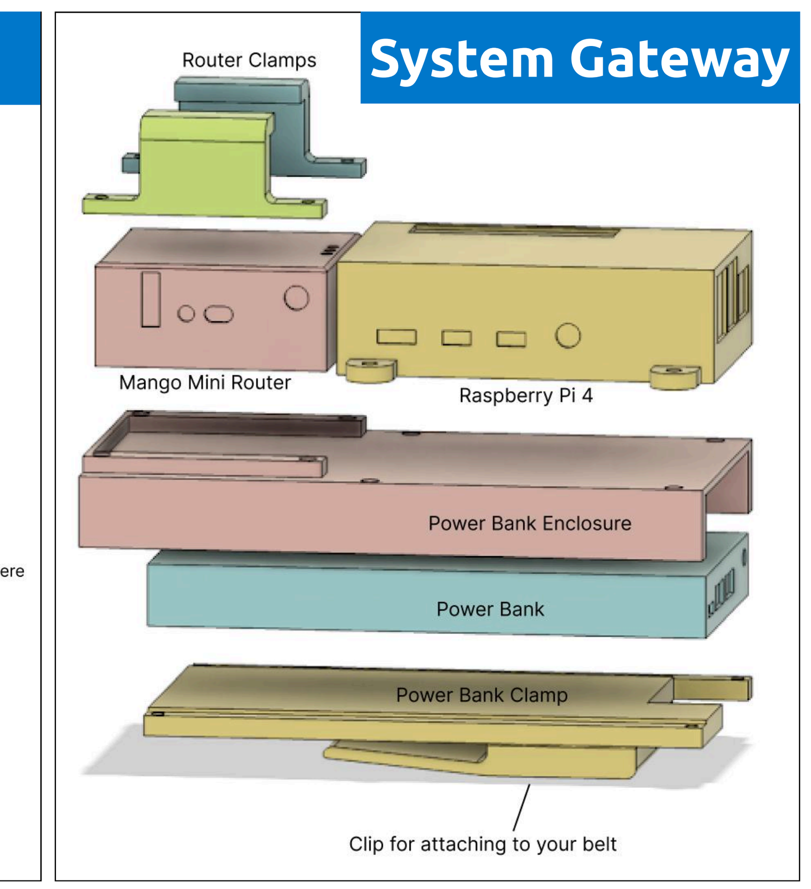
A debug dashboard was developed to assist with debugging and testing. It includes features like: manual camera inference, raw streaming, detection image and depth map visualization, real-time sensor monitoring (gyroscope, accelerometer, push buttons), manual vibration motor control, speaker management with volume adjustment and text-to-speech, and orientation calibration with graphical gauge displays.

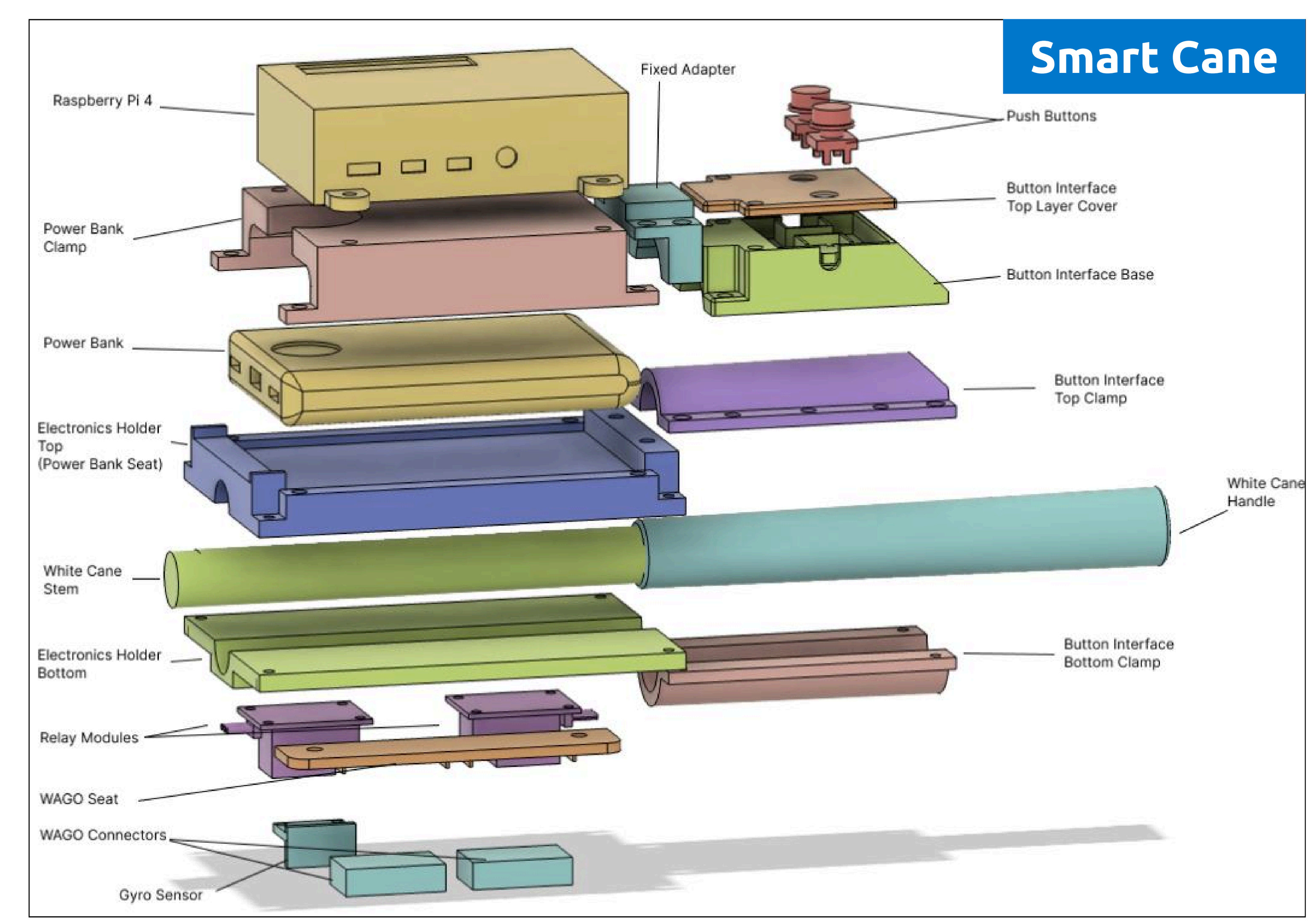


Hardware Exploded Views

Our team custom-designed and manufactured all 3D printed components for the blind person assistant device, emphasizing ergonomics and modularity throughout. The headset features a precisely calibrated 10-degree camera offset to maximize visual input while maintaining comfort and aesthetic appeal with an arc optimized to fit on the forehead surface. The System Gateway provides balanced weight distribution and includes a convenient belt clip for secure attachment to clothing or bags. The Smart Cane design enhances grip ergonomics while carefully addressing balance, weight distribution, and cable management for intuitive use. All components were fabricated using Polylactic Acid (PLA), a cost-effective and environmentally friendly bio-based plastic, with M3 heated inserts and screws ensuring durable assembly.







Conclusion

This capstone project was a valuable opportunity to incorporate feedback from visually impaired students on campus, the primary stakeholders, to enhance their indoor navigation experience. Throughout the project's development, our coding skills, 3D printing skills, and machine learning skills were refined. Our group had the pleasure of working closely with Dr. Khalid Hafeez, resulting in a technically robust and impactful project that we can all take pride in.